DESIGN AND DEVELOPMENT OF A NUMERICAL CONTROL ATTACHMENT ON LATHE

A Thesis Submitted
In partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
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to the

DEPARTMENT OF MECHANICAL ENGINEERING
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DECEMBER, 1975

CERTIFICATE

This is to certify that the work entitled "DESIGN AND DEVELOPMENT OF NUMERICAL CONTROL ATTACHMENT ON LATHE" has been carried out under our supervision and has not been submitted elsewhere for the award of a degree.

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SYNOPSIS

of the

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The present work is the development of a Numerical Control attachment for step turning on lathe without any storage medium, decoders and memory devices in comparison to an equivalent existing system. The system is developed to accommodate the workpiece of a length 1,000 mm and the diameter ranging from 25 to 150 mm.

The system follows a simple logical sequence of operations starting from the return of the carriage to the tail-stock reference end, to the automatic switching off of all the power supplies bringing all the operative units to a hault. It is a self-acting system for controlling the machining and auxiliary operations. The involvement of the operator is avoided with the system but for few initial settings. It employs the drive unit for lead screw and cross-slide separately.

The system is simple in operation with provisions to vary the feed, depth of cut as required by the situation while machining different materials.

CHAPTER I

INTRODUCTION

1.1 ASPECTS OF AUTOMATION WITH REFERENCE TO NUMERICAL CONTROL

The increase in Production capacity along with higher precision requirement has been realized by the evolution of automation of machine tools. Automation imparts rhythmical pace to the machining process and ensures stable quality of the blanks and workpieces in all stages of manufacture. The system of automation includes self-acting system for controlling the mechanisms of the machine tool to accomplish the working cycle of machining without the participation of the operator. The essential facets of automation are discussed herewith.

Almost all automatic machine tools are provided with information carrying, a storage medium for shaping the workpiece to predetermined size. This medium is kinematically linked to the operative units (in a definite manner for the given set-up) either directly (cam shaft automatics) or through a system of amplification and control (tracer controlled machine tools). Unlike these types, numerically controlled machine tool is based on the utilization of numerical data for controlling the positions, of the operative units, of a machine tool before, during and after the machining operations. The storage medium

in the N/C* machine tool may be punched data, taped input or selector switches. The information will be transformed into suitable machine instructions through the decoders etc.; on the basis of the part drawing and the operation sheet, tables are compiled listing the magnitudes, directions and rates of feed of the consecutive motions of the operative units. When the system of automation of a machine tool is considered as an integrated whole system, the concepts can be stated as

(1) The manufacturing process or sequence of machining operationswhich determines the motions of the working members, classified as main (directly participating in the cutting process) and auxiliary (not directly participating in the cutting process);

(2) Operative mechanisms of the working members for imparting the movements of their working cycle to these members;

(3) Transmitting mechanisms of the drive for the operative mechanism of the working members,

(4) Self-acting system for controlling the mechanisms of the machine tool to accomplish the working cycle of machining without the participation of the operator.

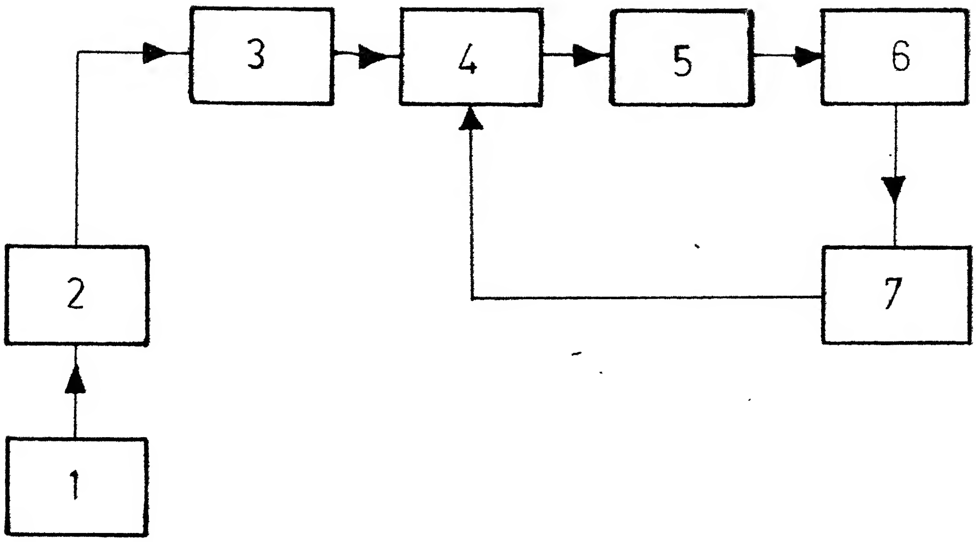
These concepts are to be considered collectively while the system is being designed.

*N/C refers to Numerical Control here afterwards.

The concept of Numerical Control was first mooted in the U.S.A. around 1949/50. The applications of Numerical Control had become manifold during the years 1960 - '74. Numerical Control is a variant of the types of control such as mechanical, electric, hydraulic, or pneumatic controls. In a system of numerical control, the operative units of the machine tool are controlled in their motion by numbers which determine the shape and size of the workpiece and which are consecutively fed into the control system.

Any control circuit for an N/C machine tool can be represented by the Fig. 1.1

The series of instructions together with the data are written in the form of a program. These programmed instructions can be stored in magnetic tapes, punched data or selector switches. The program is verified subsequently and fed into the machine tool. Decoder transforms the programmed instructions into the suitable machine instructions. The operative unit functions are governed by the drive unit. In the case of the open loop system the displacement of the slide of the operative unit is purely governed by the drive unit whereas in the closed loop system the actual position or actual displacement of a slide is monitored by the feedback unit (auxiliary measuring device) which is independent of the feed system.



1. Compiling and recording the program.
2. Verifying the program.
3. Feeding the program into the machine tool.
4 Decoding the program.
5 Operative unit drive.
6 Operative unit.
7 Feed back element

FIG.1-1 NUMERICAL CONTROL OF A MACHINE TOOL

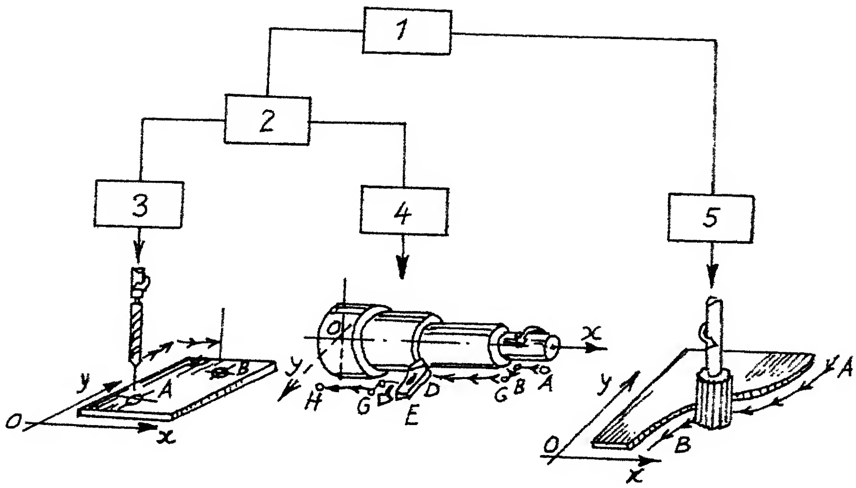
1.2.1 N/C Machine Tool & Classification

The N/C machine tool can be described as the one in which numerical or symbolic information, representing the magnitudes, speeds and directions of motion of the operative units participating in the machining of the workpiece or in positioning the workpiece and/or cutting tool is fed into the system of automatic control. The unadaptability of conventional means of automation, to small-lot and piece production, or even to large-lot and mass production under the conditions the product being frequently changed, is one of the factors those led to the development of N/C machine tools.

N/C systems are divided into finite positioning control systems and continuous or contouring control systems in accordance with their processing purpose.

In turn, finite positioning control systems are classified as

(1) Systems for setting coordinate dimensions without definite linear motion between the points machined (the operative units can travel simultaneously but with no inter relation). In machine tools with such N/C systems the processing operation is performed after the operative unit has reached its coordinate position. Such systems are called as point-to-point systems.



1- N/C 2-Finite positioning controls 3-Point-to-point system
4- Straight line systems 5-Contouring systems

FIG.1.2. CLASSIFICATION OF N/C SYSTEMS ACCORDING TO THE PROCESSING FEATURES

(2) Systems with rectilinear consecutive movement of the operative units, parallel to the directions of travel of the operative units, from point to point in the process of machining the workpiece. Such systems are called as straight line systems.

In the continuous or contouring control systems, there are continuous, inter-related, motions of the tool and workpiece along different coordinate axes, thereby enabling curvilinear contours or surfaces to be machined.

Point-to-point N/C systems are used in drilling and boring machines, straight line systems are used in lathes and contouring systems are used in milling machines.

1.2.2 Programming and Recording the Information

In order to meet the demands of small-lot and piece but repeating production and lot production with a frequently changed product certain standard instructions, compiled in the form of a concise program are to be fed into the machine tool. Programming aspect includes the minimization of instructions for a specific shape to be obtained on the workpiece. The program, duly checked, is recorded in punched paper tape or magnetic tapes. The primitive N/C used selector switches.

The punched paper tapes are of standard dimensionswith definite positions on them for punching the

instructions. The coding of the instructions is mostly similar with small deviations depending on the firm, making the N/C machine. While the punched paper tapes are cheap and easily replaceable on the event of wrong punching of the program, the magnetic tapes can store more information for the same square area. The information from the punched storage medium can be read by special devices wherein the mistakes could be rectified.

1.2.3 Drive for Operative Unit

The driving of operative unit with finite control are achieved by

(1) Stepped electromechanical drives
(2) Infinitely variable electric drives
(3) Pneumatic hydraulic drives
(4) Stepped and infinitely variable hydraulic drives
(5) Stepping motors for incorporation in digital incremental control systems.

Feed systems employing stepped drives are widely used for positioning and straight-line control systems in conjunction with on-off switching circuits. The robustness and simplicity gives electro-mechanical drives many advantages. About one-half of the numerically controlled machines that have been installed throughout the world to-date are equipped with electro-hydraulic drives owing to their ability to face the difficult machining conditions.

The evolution of the stepping motors set aside the use of the other drive units due to the possibility of meeting high torque requirements, in machine tools, with hydraulic torque amplifiers. A stepper motor may be described as an actuator that transforms an electrical input pulse into an incremental mechanical output displacement. The stepping action results from sequential excitation of the two phase windings. The stable rotor position at any instant is in the position of maximum magnetic attraction between the permanent magnet and the field set-up by excitation of the windings. The main advantages of stepping motors are

1. When driven with digital pulses, it moves one and only one step per pulse.
2. It is self starting and no external means required.
3. Rapid acceleration, stepping are achieved including reversal without an external arrangement.
4. It starts, stops and reverses instanstaneously.
5. The torque to input power ratio is higher compared with conventional motor.

1.2.4 Displacement Measuring Systems

The displacement measuring systems can be either digital or analogue. The digital displacement measuring process can be either incremental or absolute. In the

incremental process the instantaneous position of a machine slide can be obtained by summing all the increments. The digital incremental methods include (1) Photo-electric scanning method for rotary motion (2) Inductive scanning with a toothed wheel, and the digital absolute methods include

(1) Scanning using switched scanning zones

(2) Photo-electric scanning of discs with gray coding.

Out of all the processes, the rotary measuring system with photo-electric scanning is widely used.

Unlike digital methods, analogue methods do not have any finite quanta and the quantity to be measured is converted into some other analogous physical quantity which is more convenient to measure and to process. These include (1) Synchro as an inductive angle measuring device (2) Linear Inducto syn (3) The Accupin.

In the analogue methods the resolution capacity of the measuring system, the response sensitivity of the comparator and the inaccuracies in the mechanical components forming the transducers are the sources of errors.

In considering a N/C machine tool, the control system is not to be isolated from the machine. In view of the trend the development is taking, to have the highest possible degree of utilization and achieving the high accuracy, the machine tools are to be very robust and solid

in construction. Furthermore, modifications in the classical design are to be brought to utilize the full performance of an N/C machine tool of which the control system is capable. It is worth mentioning at this stage about the use of recirculating ball screw to eliminate backlash.

1.3 SCOPE OF THE PRESENT WORK

The major objective of the present work is to develop a numerical control attachment, without any storage medium, decoders, memory devices, for step turning on a centre lathe. The system is developed to accommodate the workpiece of length ranging upto 1,000 mm, diameters ranging from 25 to 150 mm. It can also be used for step turning of workpieces of different materials. The simplicity entrained with the system avoids the complex units otherwise needed. It has provision to vary the feed, depth of cut as required by the situation arising while machining different materials.

The system follows a simple logical sequence of operations. It needs the drive unit for lead screw and cross slide separately. Owing to the advantages associated with, stepper motors are used to drive these operative units. Except for a few initial adjustments, it does not need programming of instructions when compared to an equivalent N/C system. It is a self-acting system for controlling the machining and other auxiliary operations.

The advantages of the system are:

(1) Simple in operation to an equivalent N/C system.

(2) Does not need programming thereby avoiding the possible errors

(3) Storage medium, decoders are not needed which drastically reduces the cost and avoids the complications thereof.

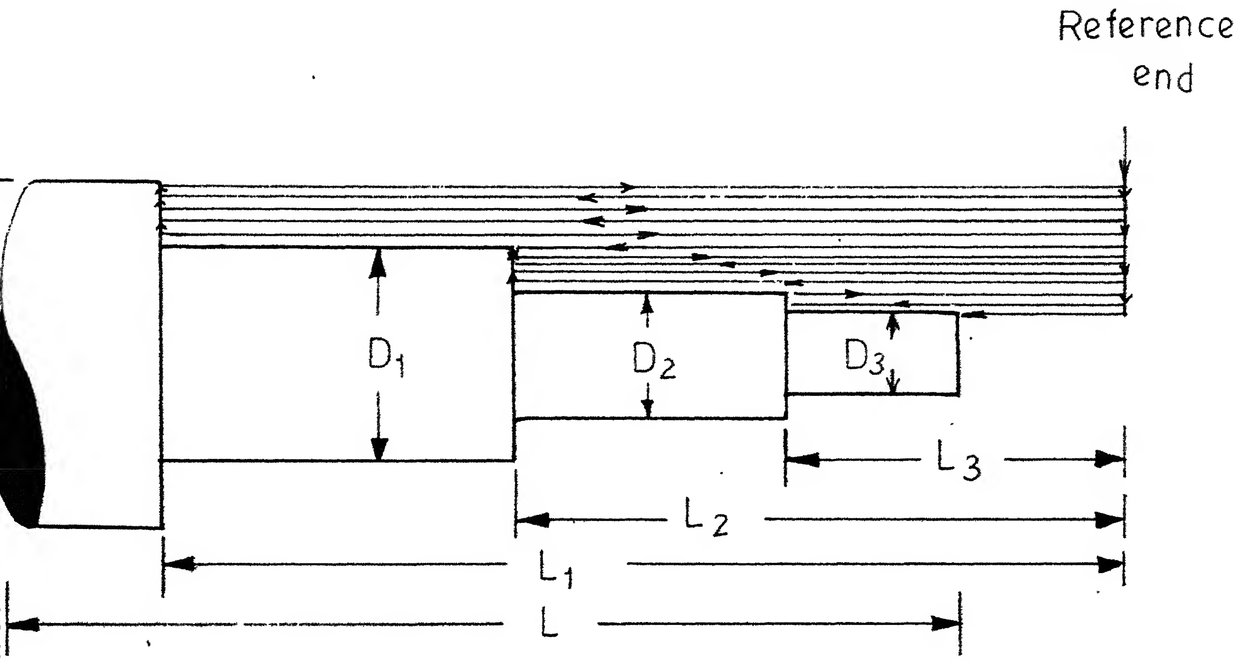
CHAPTER II

DESIGN OF THE CONTROL SYSTEM

2.1 INTRODUCTION

The sequence of operations involved in the step turning process is as shown in the Fig. 2.1. To start with at the tail-stock reference end the tool moves by a pre-determined distance in the forward direction thus by setting the depth of cut for the cutting operation. The cutting of the material continued till the set length is covered. The reversal of the cross slide by a pre-determined distance returns the tool. The carriage returns to the tail-stock reference end. The sequence follows till the required step is achieved. The number of passes is being determined by the setting of depth of cut. Same sequence is being followed in obtaining the subsequent steps.

The present system controls the sequence of operations, involved in the step turning of a workpiece, logically. The first phase of the sequence is initialization which ensures the return of the carriage to the tail-stock reference end and keeps the system ready for the next phase of operations. Furthermore, initialization assures certain adjustments to be made as per the workpiece dimensions and the required shape of the job. Machining operations proceed in the direction from tail stock end towards head stock.



D – Initial Dia. of work piece.

D_1-D_2-D_3 – Step diameters of the work piece after finishing.

L – Initial Length of work piece.

L_1-L_2-L_3 – Distances moved by the tool in each stage of cutting.

FIG.2.1. SEQUENCE OF CUTTING OPERATIONS

Certain pre-determined time delay is provided for the cross slide movement ensuring the setting of the tool corresponding to a finite depth of cut. It follows the forward motion of the carriage. The forward cutting motion is governed by the initial adjustment on the control panel corresponding to the step length required. Once the tool cuts the workpiece as governed by the initial adjustment, the carriage stops from moving. Then the tool is retrieved by a predetermined distance. It is essential to return the tool, firstly to prevent the tool from rubbing the machined surface which otherwise would be affected, secondly to reduce the tool wear. The returning of the tool by a small distance is also achieved by the definite time delay provided. Next follows the return of the carriage to the tail stock reference end. This completes one pass. The number of such passes to get one step is determined by the workpiece diameter and the required step diameter for a definite depth of cut pre-selected. The system, after obtaining the required step, switches on to the stage corresponding to the subsequent step. The same sequence follows. The forward tool motion in this case is from the position to which the tool is retrieved in the earlier stage. The present system is designed to obtain three steps only, though it can be easily extended for any number of steps with slight changes, hence after the completion of the third step it stops by itself. The completion of the cutting operations

makes the power supplies off. This is an essential facet of the automation.

2.2 DESCRIPTION

The essential feature of the present system is to minimize the input data to be fed to the machine in order to execute the logical sequence of operations. Emphasis has been laid to build up the logic within the system by which it would be self acting thus by needing a fewer initial adjustments.

To start with, the pressing of the push button on the control panel ensures the pre-setting of flip-flop ($\overline{Q}$ High) and 4-bit shift register. The helical potentiometers are also to be adjusted as per the required step lengths and diameters. The main motor and the feed motor would be on by pressing the 'start' switch. The carriage moves on, to the tail stock end, from the position wherever it was earlier. As it traverses towards the tail stock reference end, it hits the limit switch roller. The limit switch which has an N C* and N O* contacts gets its contact positions changed. The changeover is followed by the forward cross slide movement being governed by the definite time delay (the delay period can be varied by the knob on the control panel). This sets the tool for a definite depth of cut. The setting of the tool is preceeded by the

*N C refers to Normally Closed
N O refers to Normally Open

forward carriage movement performing the cutting operation. The forward carriage movement is governed by the feed comparator output. Once a pass is completed, the tool is withdrawn by a pre-determined quantity to prevent the rubbing of the tool against the machined surface. Then the carriage moves towards the tail stock reference end and the movement is haulted by the limit switch. Next, the time delay for cross slide sets the tool for further depth of cut and the sequence follows. The number of passes and setting of the depth are controlled by the depth and feed comparators which are in turn governed by the initial helical potentiometer adjustments. The sequential comparator, designed for three steps in the present case, switches to the next step automatically once a step is obtained. This is achieved by the resetting of the shift register by the clock derived from anding of the depth and feed comparator outputs. When the depth and feed comparator outputs are low the shift register is re-set. Though it is designed for three steps in the present case, it can be easily extended to more number of steps. After the completion of the job to the desired shape the main motor power supply, the power supply to the feed and cross slide motors are put off automatically. Hence less involvement of the operator is necessary once the initial adjustments are made. Practically there are very few limitations with respect to the size of the workpiece (length and diameter) other than those imposed by the capacity of the lathe itself.

The logic can be represented in the form of an algorithm as per below.

```
   DIMENSION D(3), L(3)
   READ, (D(I), L(I), I=1,3)
   Q̄=1.0
   Q=0.0
   DO 15 NX=1,3
22 REVERSE FEED
   IF (DEPTH COMP. OUTPUT LOW) GO TO 15
C  L.S.N.O CLOSES
   FORWARD CROSS SLIDE FINITE TIME DRIVE
   Q=Q̄
   FORWARD FEED
   IF (FEED COMP. OUTPUT IS LOW) REVERSE CROSS SLIDE
1  FINITE TIME DRIVE
   GO TO 22
15 CONTINUE
   STOP
   END.
```

These are not fortran statements. The block diagram showing the logical sequence and flow of information is shown in Fig. 2.2

2.3 LOGIC CIRCUIT

The block diagram of the logic circuit can be realized with regard to the essential elements as shown in Fig. 2.3 Sequential instruction register or shift

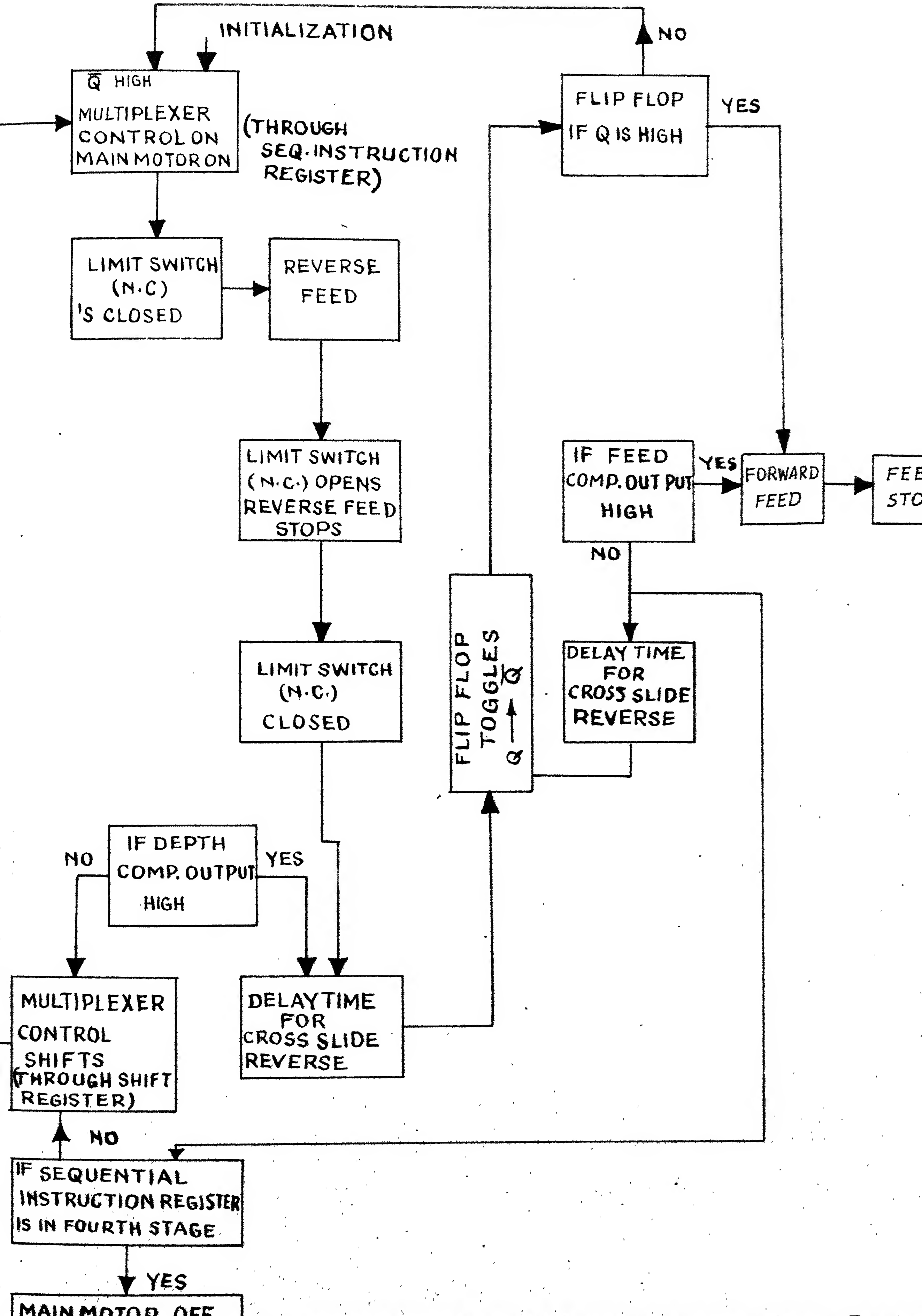


FIG 3.3 SCHEMATIC LOGIC DIAGRAM

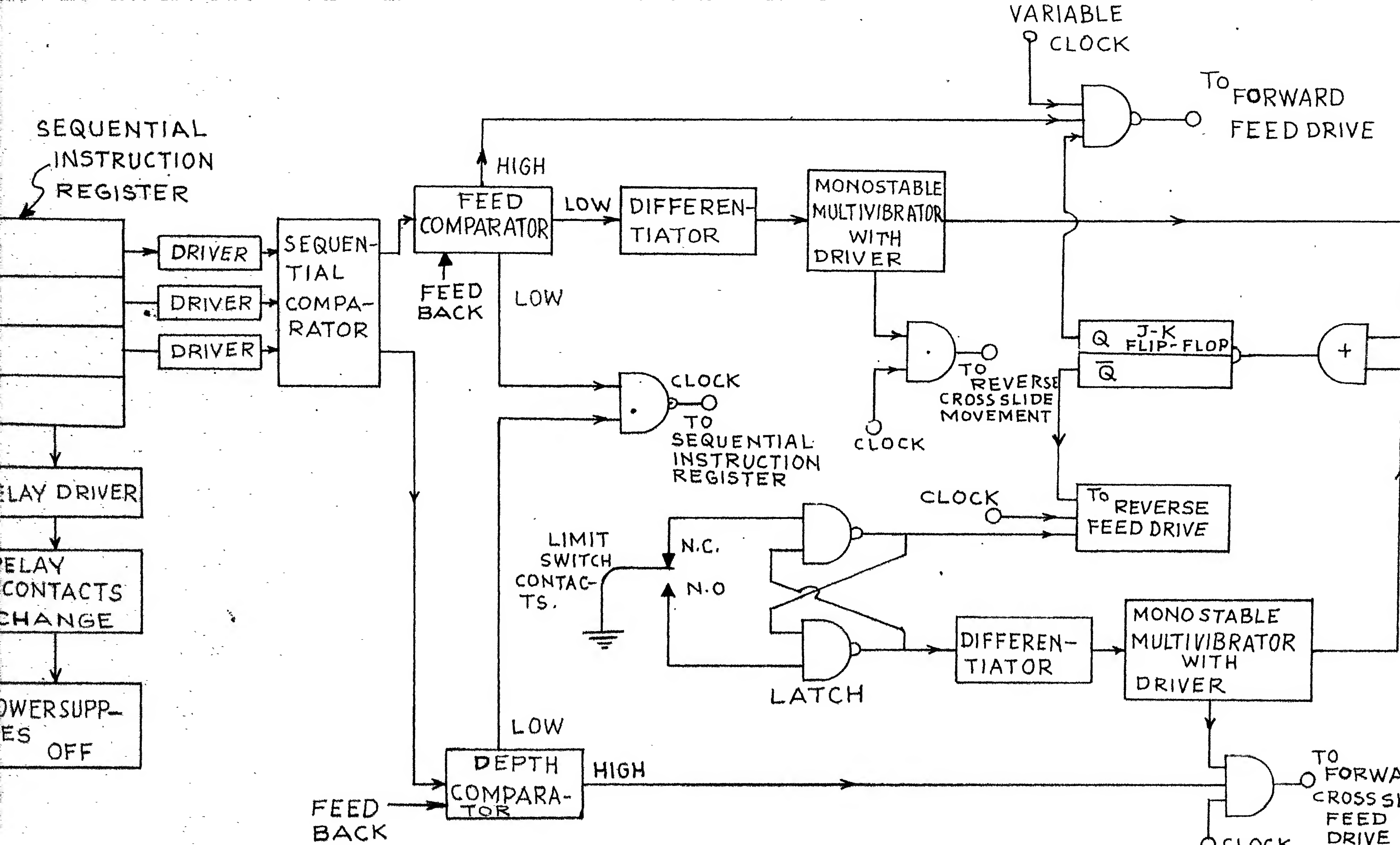


FIG.2.3. LOGIC CIRCUIT OF THE SYSTEM

register conveys the instructions to the respective parts sequentially. Without the involvement of operator, it switches on to the subsequent stages. In the present case the fourth stage is for automatic stopping of the functioning of the logic and the main motor. The instructions are being carried to the sequential comparator through three individual driver circuits. The sequential comparator is used to control the acquisition of samples of analog signals. It can be otherwise called as a multiplexer. The number of channels in a multiplexer can vary from two to several hundred, subject to certain practical limitations. It essentially controls the flow of information. The signals from the multiplexer would be command signals for the feed and depth comparators.

The output of the feed comparator, depending on the command signal and slave signal, governs the forward carriage movement. Similarly the output of the depth comparator determines the number of passes in obtaining the step of required dimensions. If the depth and feed comparator outputs are low the sequential instruction register is reset to change over to the command signals corresponding to second subsequent step. Higher feed comparator output ensures forward carriage movement. The transition from high to low is made use of to withdraw the tool by certain predetermined distance.

The limit switch which has N C and N O contacts will limit the reverse movement of the carriage at the tail stock reference end. One of the contacts controls the forward cross slide movement by a predetermined amount.

The flip-flop outputs Q and $\overline{Q}$ command the forward and reverse carriage movements. Initial setting of flip-flop makes $\overline{Q}$ high ensuring the return of the carriage to the tail stock end from the position wherever it was in the earlier stage. The triggering of the flip-flop is by the output of the 'OR', the inputs being from the monostable multivibrators, duly differentiated at the trailing edge.

Two monostable multivibrators are being incorporated to meet the time delay needed for the forward and reverse cross slide movements. The first movement is for setting the depth of cut and the later is to withdraw the tool. The timedelays are variable depending on the requirements.

CHAPTER III

DESIGN OF MECHANICAL ACCESSORIES

The present system is developed to equip the Kirloskar lathe with two independent controls for the cross-slide and carriage movements. The Kirloskar (Harihar) MBD-2 type lathe is used for the purpose. The gear box of the machine is removed and in its place the lead screw is extended with a shaft, to the extreme end of head-stock side wherein the feed drive unit is mounted. The two modifications, namely the control of the independent carriage and cross-slide movements by external means, do not alter the working condition of lathe to considerable extent.

3.1 CROSS SLIDE DRIVE UNIT

The cross-slide is driven by a stepper motor the speed of which is controlled through external means. The control of cross-slide movements is vital with regards to the setting of depth of cut, retrieval of the tool in the return stroke. The stepper motor is coupled directly to the cross slide shaft. The stepper motor has a double ended shaft. The logic needs feedback to ensure the information to be fed to the comparator the distance by which the tool moved in setting the depth of cut in every pass thereby determining the number of passes in obtaining a

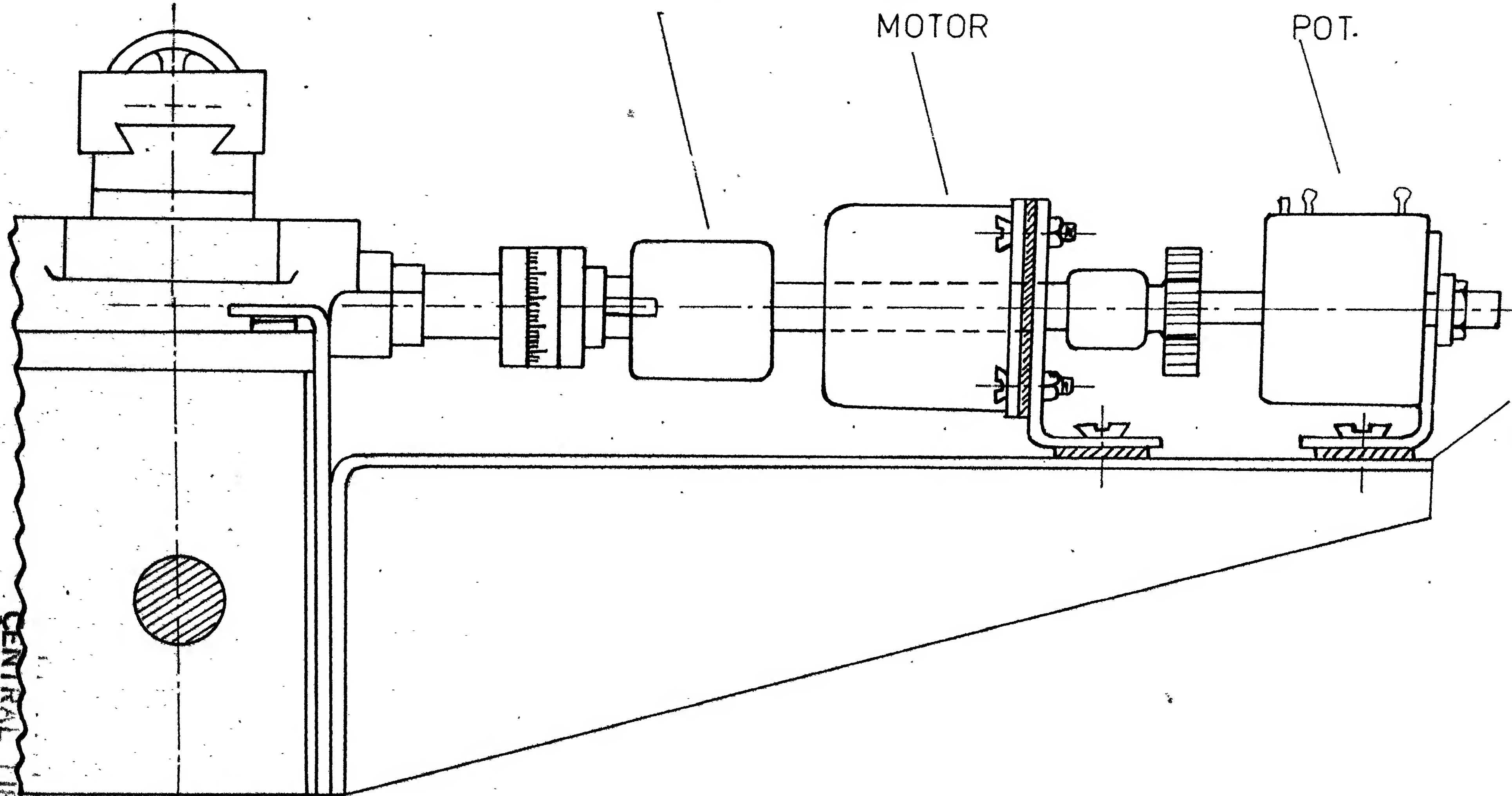


FIG.3.1. CROSS SLIDE DRIVE ASSEMBLY

particular step. The stepper motor shaft rotation is registered in the feedback potentiometer through a reduction gear train. The maximum and mihimum diameters of the workpiece that the Harihar Lathe can accommodate is 150 mm and 25 mm respectively. The range to be covered by the cross-slide is half the difference in diameters. The gear train transmits the cross-slide rotation to the feed-back potentiometer covering the range. The feed-back potentiometer mounted is shielded from spurious signals. The details of the cross-slide drive unit are shown in the Fig. 3.1. The cross-slide movement by the stepper motor is only to set the pre-determined depth of cut and to retreive by a pre-determined distance hence the forces during cutting do not appear into picture.

3.2 FEED DRIVE UNIT

The carriage of the lathe can be engaged to the lead screw. In an ordinary lathe the automatic movement of the carriage is achieved by the gear train, at the head-stock side, coupling the lead screw to the main motor shaft. In the present case the lead screw rotation is independent of the main motor shaft rotation. By keeping the carriage engaged to the lead screw, its movement is controlled by external means.

In designing for the motor ratings for such drive several forces are to be taken into consideration.

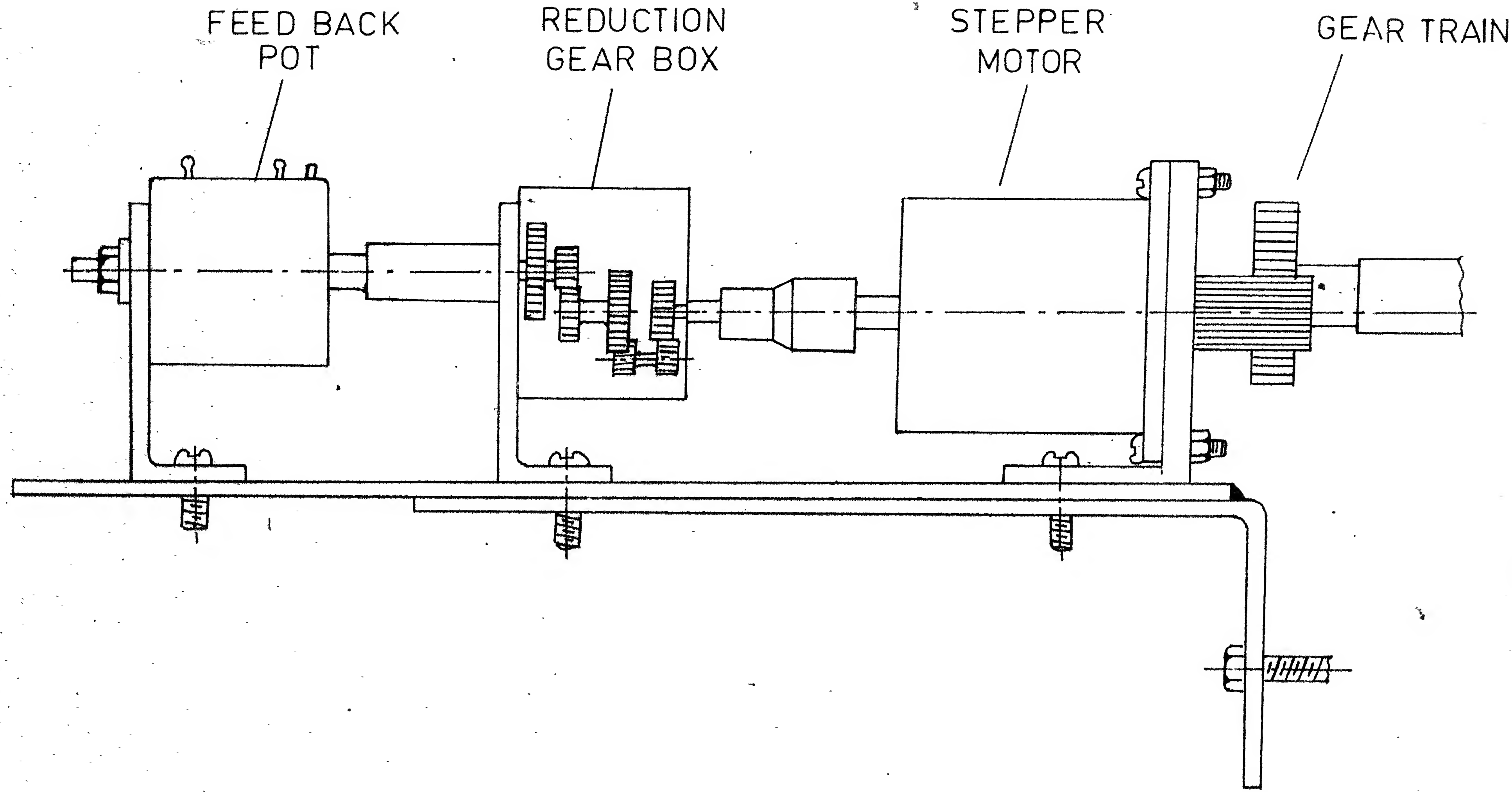


FIG.3.2. FEED DRIVE ASSEMBLY

For a feed of 0.1 mm/rev. of spindle when the speed of the lathe is 750 r.p.m, the torque requirement of the lead screw is calculated to be nearly 4 kg-cm during cutting, the lead screw rotating at 30 r.p.m. Actual torque required to move the carriage against static forces is found to be 6 kg-cm. A simple experiment is conducted in finding the torque required at the lead screw to move the carriage. It involves, simply, application of load to the wire rope partly wound on a drum mounted on the lead screw till the lead screw rotates when the carriage is engaged to it. The load multiplied with the arm length gives the torque required. The torque capacity of the stepper motor is 10 kg-cm. It is being boosted up by a gear reduction of 1 : 4 from motor/lead screw. Under the conditions in which the stepper motor generates 10 kg-cm torque, the carriage can be moved against static and cutting forces. For thecarriage ovement over the full bed length the 500 rotations of lead screw and hence 2000 revolutions of the stepper motor shaft. The range is represented in the potentiometer by the help of reduction gear box with a reduction ratio of 1/62. The feed back pot is protected from spurious signals by suitable shielding box. The parts mounted on the platform are tested for alignment while they are in operation. The details of the unit are shown in Fig. 3.2.

3.3 LIMIT SWITCH

The role of the limit switch in limiting the return travel of the carriage is important. It is mounted on a C.I block which can be fixed on the slide-way at any position. This avoids much over travel in machining small jobs.

3.4 CENTRAL CONTROL PANEL

All the control switches and the other accessories involving initial adjustments are provided on the central control panel under suitable heads ensuring the operator to follow the operations without any confusion. The details of central control panel are shown in Fig. 3.3

CHAPTER IV

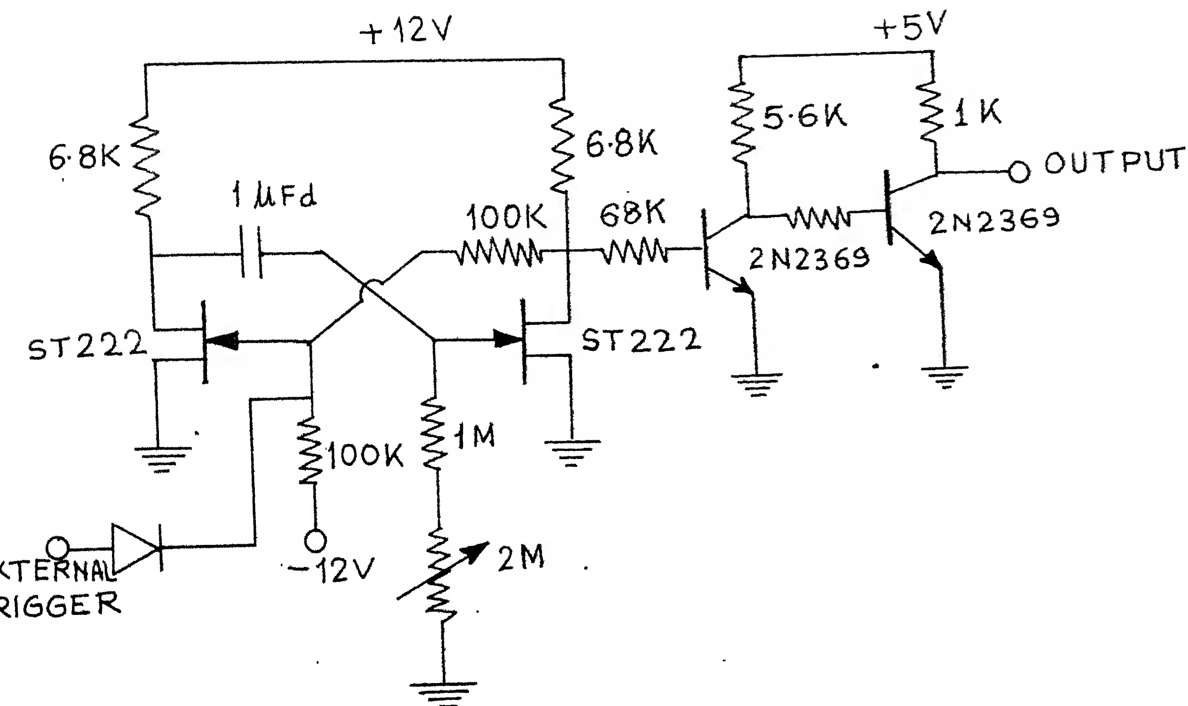
DESCRIPTION OF ELECTRONIC CIRCUIT

4.1 DELAY ELEMENTS

Two monostable multivibrators are employed in the present scheme for the delay elements. The delay time of the monostable multivibrator is determined by certain circuit parameters. When an external pulse triggers the monostable it functions, with the effect the output would be high to the period given by the time delay and springs back to the original state. Forward cross slide movement, by a pre-determined distance, is achieved by allowing the cross slide motor to rotate for a finite time as determined by one of the monostable multivibrators. The reverse cross slide movement, for the tool withdrawal, is achieved by the other monostable multivibrator. The time delays of the monostables can be varied. The circuit of a typical monostable multivibrator is as shown in the Figure 4.1.

4.2.1 Sequential Instruction Register

In the present scheme, the depth of cut and feed for tool movements are to be controlled at a time and sequentially the control has to shift over to the next set of input analog signals for the subsequent operations. Hence a 4-bit shift register is used to shift the control from one step to the subsequent steps sequentially after



DELAY ELEMENTS WITH DRIVER

HE DELAY ELEMENT II has capacitance of 0·47 μFd. and resistance of 100K & 1M (↗)

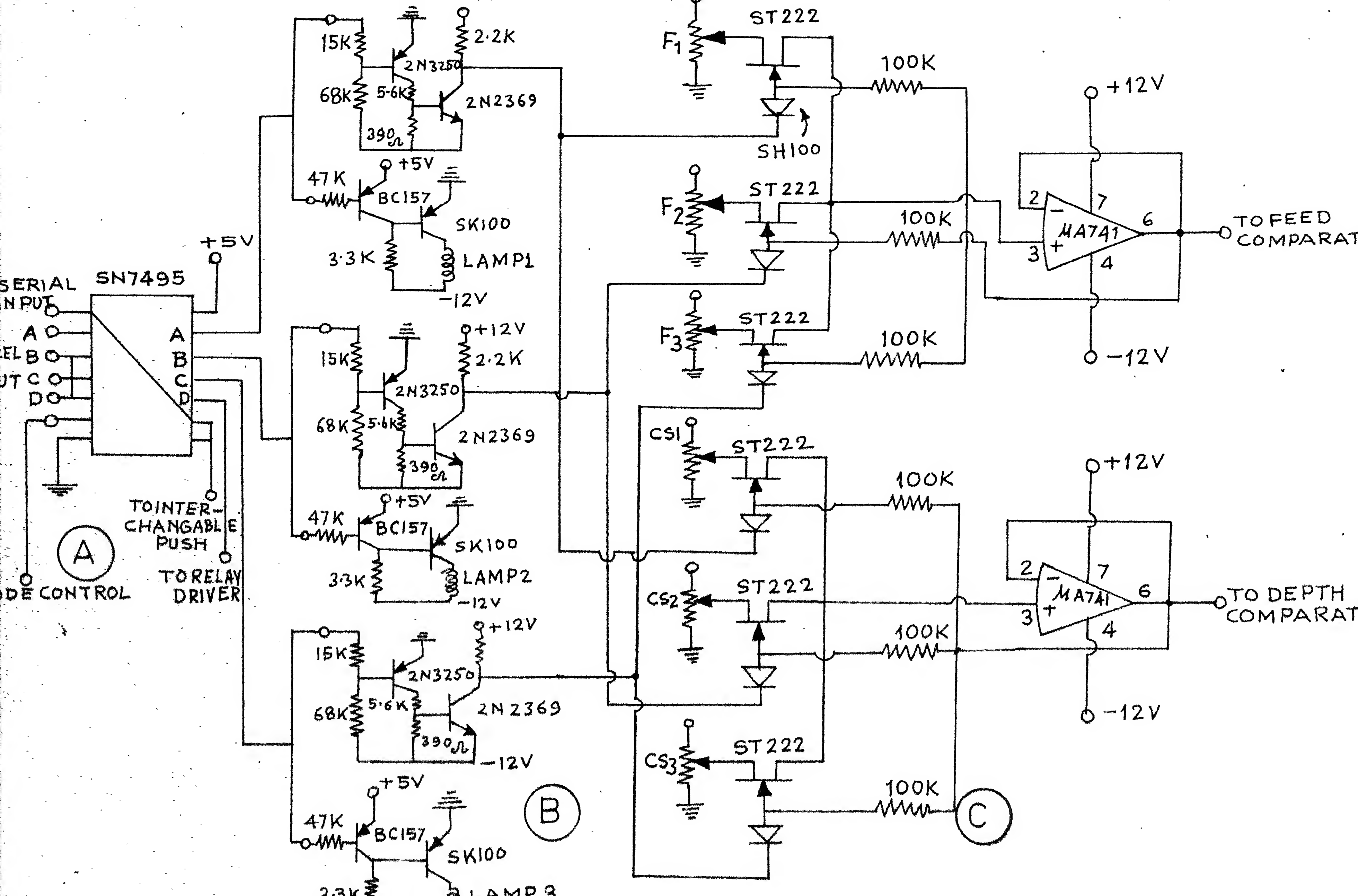
FIG. 4.1. MONOSTABLE MULTIVIBRATOR (WITH DRIVER)

the completion of the earlier task. Three of the outputs of the shift register are the logical control inputs to the three multiplexer drivers. The fourth output is to control the relay contacts, through a driver, in order to stop the rotation of main motor and functioning of circuit. The pin connections of the shift register employed are shown in Figure 4.2.

4.2.2 Sequential Comparator

Sequential comparator is otherwise called as multiplexer. In the present scheme digital signals are used to control the acquisition of samples of analog signals. In such applications the desired characteristics of the operational amplifiers are high input impedance, low bias current, low voltage drift, and fast response to transient signals. Multiplexers are used in such cases to reduce the number of components and to process more than one analog signal. The number of channels in a multiplexer can vary from two to several hundreds.

The most commonly used switches in modern multiplexer designs are the JFET transistor and the MOS FET transistor. The preference for these switches is due to the excellent DC isolation between the switch driver circuitry and the analog signal path they provide. The multiplexer designed to suit the requirements in the present scheme controls the acquisition of analog signals



SEQUENTIAL INSTRUCTION REGISTER

from the feed/depth helical potentiometers. The switch drivers get logic control inputs from the sequential instruction register. The gate follows the analog input since the gate-to-source voltage of a JFET is zero when the device is turned to ON after receiving input from the driver circuit.

4.3.1 Control of Carriage and Cross Slide Movements

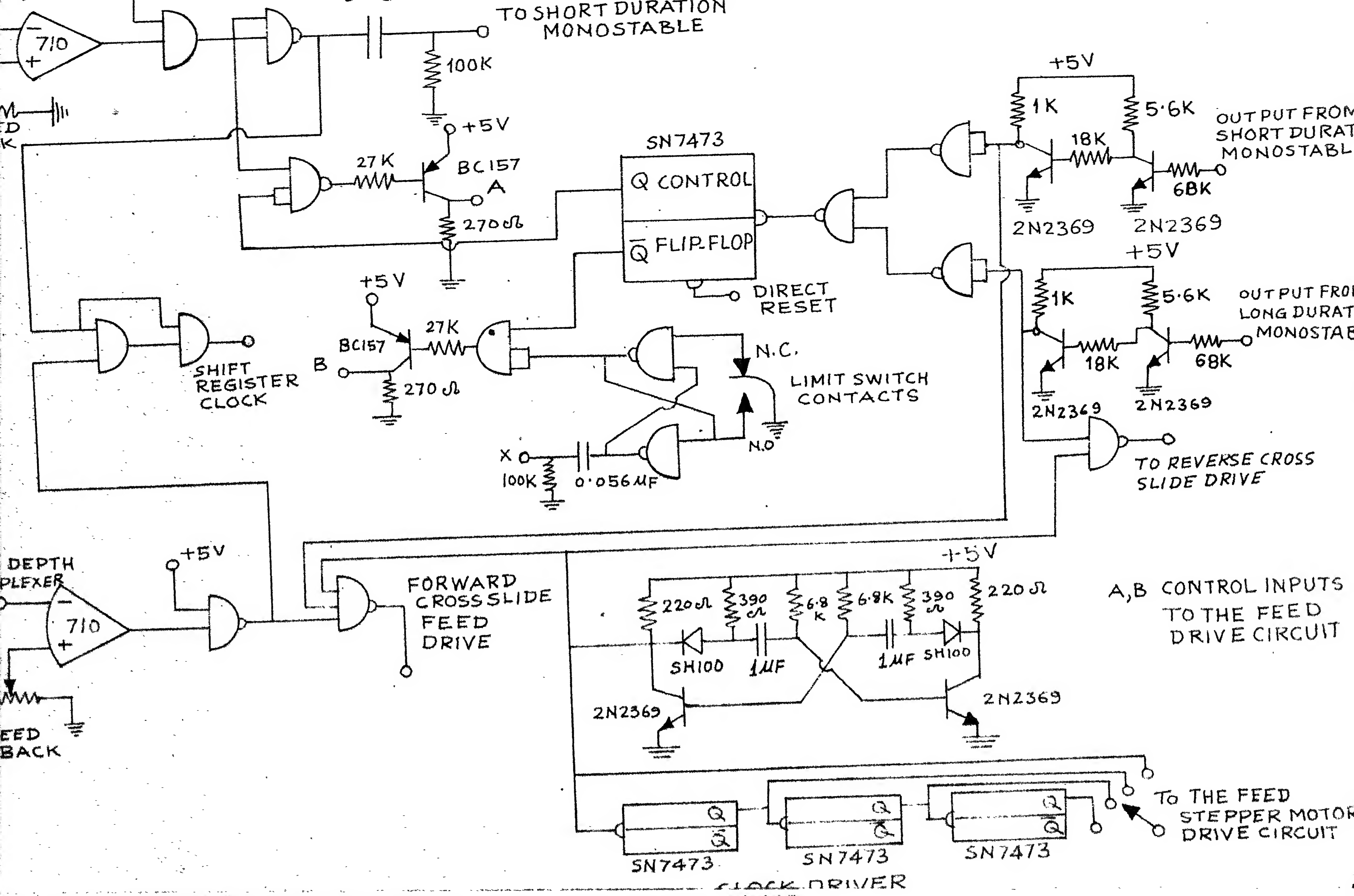
The forward and reverse motions of the carriage are controlled by the feed comparator output. The comparator output is inverted and fed to the three input Nand. The output of this Nand is inverted and made as the control input in the two phase clock control circuit. The output Q of the control flip-flop monitors the output of the gate, along with the comparator output. The forward movement of the carriage is ensured as long as the state Q and the inverted comparator output are high.

The change in the output of the feed comparator is used through an inverter and a differentiator for positive triggering of the short duration monostable providing the time delay for the reversal of cross slide by an adjustable predetermined distance. The output from the monostable is used through an inverter to trigger the control flip-flop making $\overline{Q}$ high.

The output $\overline{Q}$ of control flip-flop is fed to the Nandalong with the output from normal closed contact of limit switch through a latch. The output is inverted and used as the second control input B in the two phase clock circuit. Once the carriage reaches the tail stock end it hits the limit switch changing over the limit switch contact positions. The reverse motion of the carriage, thereby stops. The change over of the contact positions of microswitch also triggers, through latch output and the differentiator, monostable (for long duration). The delay period of monostable is adjustable as provided on the control panel.

The multiplexer output for depth comparator is compared with the feedback pot voltage when the cross slide motor is on. The forward and reverse cross slide movements are achieved through a stepper motor mounted there of. The principle of the motor drive circuit is described in section 4.3.2. The forward movement of the cross slide is governed by the depth comparator output as shown in Fig. 4.3. As long as the monostable (long duration) output and the comparator outputs are high the forward movement continues.

The sequence of operations is executed as many times as determined by the set depth of cut and the step diameter. The change over of the states of both the comparators, simultaneously, resets shift register through a Nand and an inverter as shown in the Fig. 4.3.


TO SHORT DURATION MONOSTABLE
710
100K
+5V
27K
BC157
A
270Ω
SN7473
Q CONTROL
Q̄ FLIP-FLOP
DIRECT RESET
+5V
1K
5·6K
18K
68K
2N2369
2N2369
OUTPUT FROM SHORT DURAT MONOSTABL
+5V
1K
5·6K
18K
68K
2N2369
2N2369
OUTPUT FRO LONG DURAT MONOSTAB
SHIFT REGISTER CLOCK
+5V
BC157
27K
B
270Ω
N.C.
LIMIT SWITCH CONTACTS
N.O
X
100K
0·056μF
TO REVERSE CROSS SLIDE DRIVE
DEPTH PLEXER
710
+5V
FORWARD CROSSSLIDE FEED DRIVE
EED BACK
+5V
220Ω
390Ω
6·8K
6·8K
390Ω
220Ω
SH100
1μF
1μF
SH100
2N2369
2N2369
A,B CONTROL INPUTS TO THE FEED DRIVE CIRCUIT
SN7473
SN7473
SN7473
Q
Q̄
To THE FEED STEPPER MOTOR DRIVE CIRCUIT
CLOCK DRIVER

4.3.2 Stepper Motor Drive Unit

The stepper motor converts electrical digital information into mechanical movement. The torque is developed as a result of the interaction of an alternating magnetic field, produced by a stationary multiphase winding and on unidirectional flux. The rotor aligns itself into the position of minimum reluctance when excited in the case of a single phase winding on the stator. The rotor position is changed by sequential switching of the multiphase winding on the stator. The motor is characterized by numerous toothed positions on stator as well as on the rotor. If the rotor teeth are at a pitch where it has one more tooth than the stator for each four poles of the stator, assuming a two phase winding there on, then the rotor will advance one tooth pitch for each complete cycle of operation. Bifilar wound stepper motors are in more common use where in instead of reversing the current in a winding, the current of the same polarity is switched to an identical winding wound in the opposite direction. The simple switching sequence, of a fifilar wound stepper motor is shown in Fig. 4.3.2.

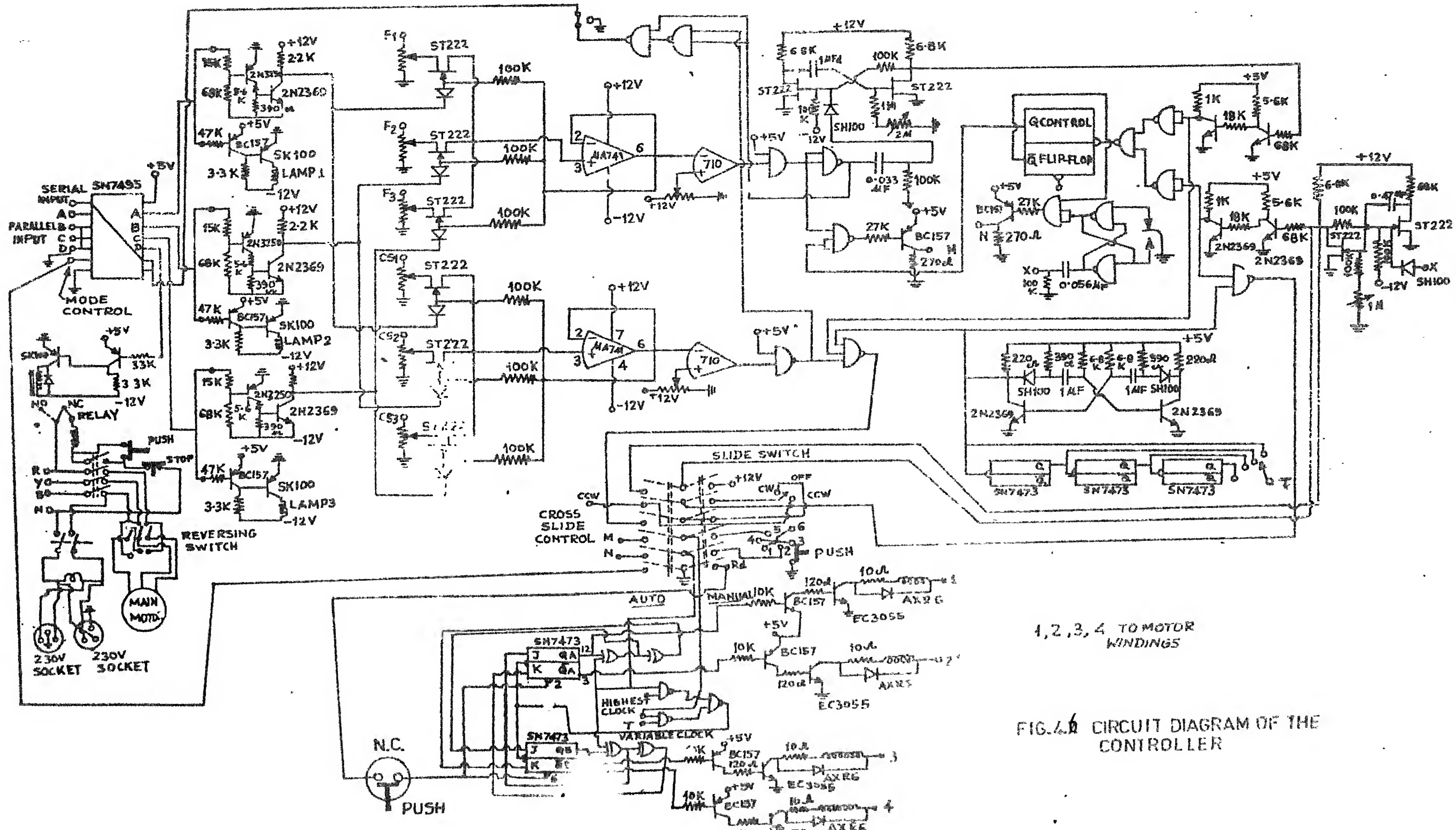


FIG.4.6 CIRCUIT DIAGRAM OF THE CONTROLLER

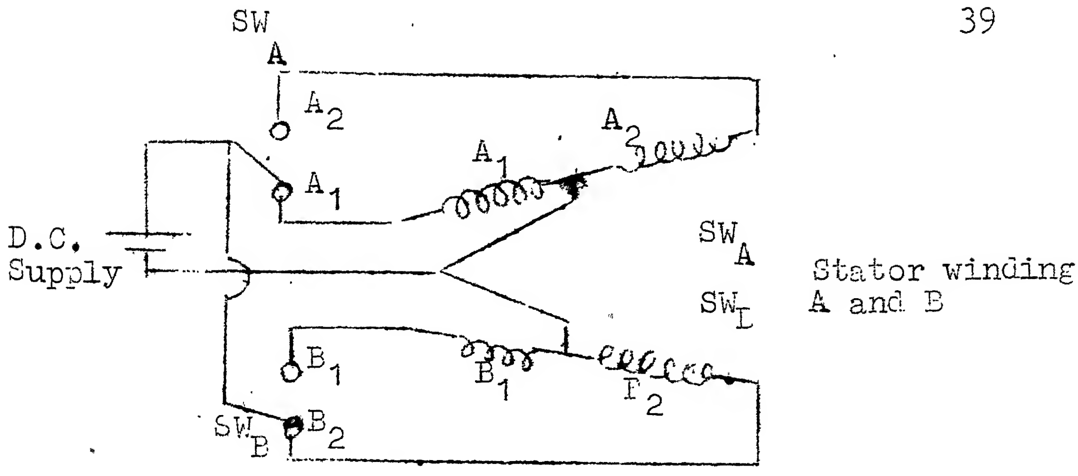


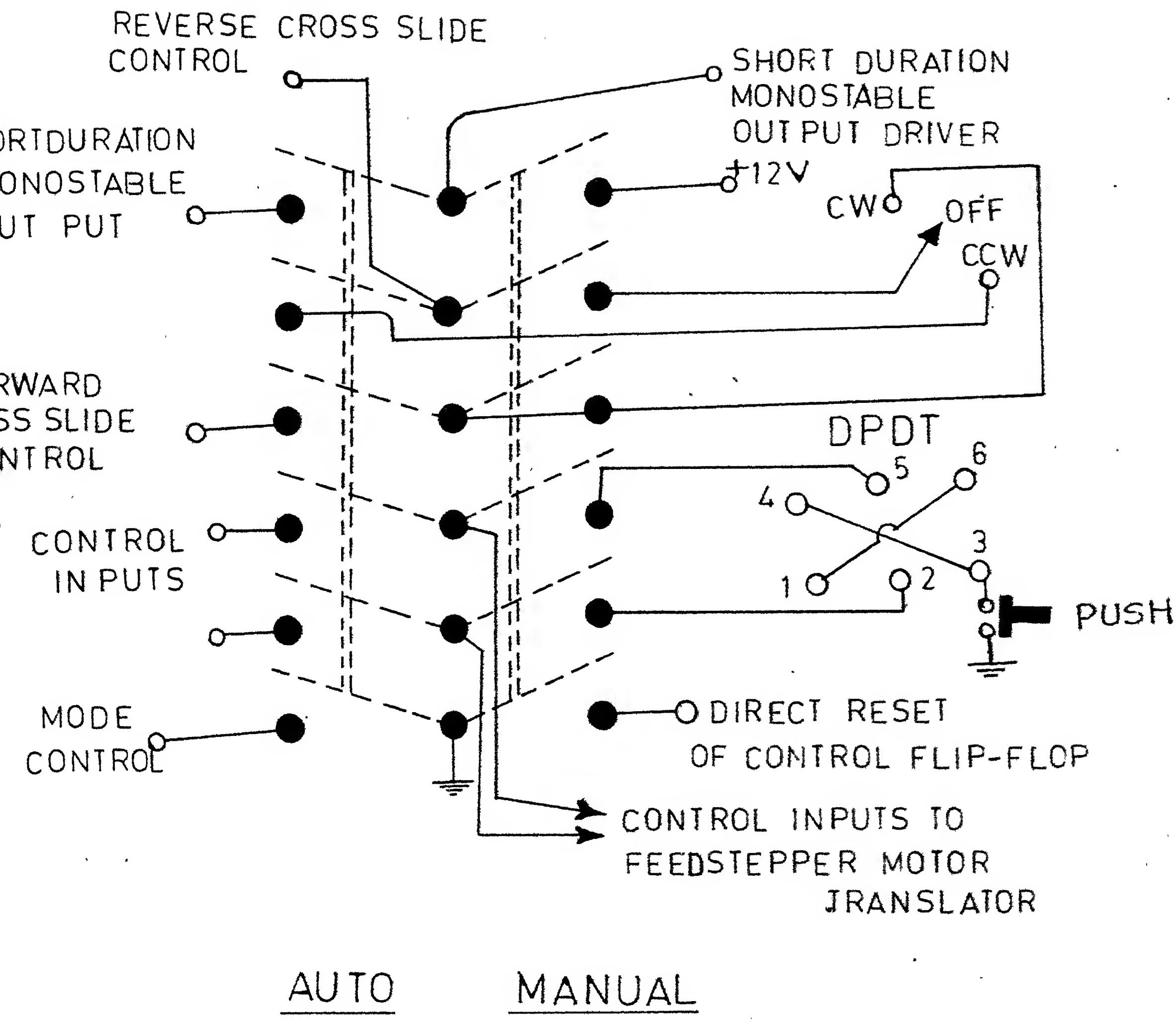
Fig. 4.3.2 SWITCHING SEQUENCE FOR A BIFILAR WOUND STEPPER MOTOR

STEP	STATE OF WINDING			
	C.W	C.C.W	C.W.	C.C.W
1	A_1	B_1	A_1	B_1
2	A_2	B_1	A_1	B_2
3	A_2	B_2	A_2	B_2
4	A_1	B_2	A_2	B_1

The sequential switching and the other require - ments of the stepper motor such as 0.5 amp supply at 12V to each winding is done by the translator unit alongwith the oscillator and power supply.

4.4 AUTO-MANUAL SWITCH

The system is equipped with an auto-manual switch to incorporate the manual adjustments when the logic is not in execution. This ensures the setting of the carriage and cross slide at the desired position.



(CW, OFF, CCW REFER TO THE CONTROLS ON THE CROSS SLIDE STEPPER MOTOR TRANSLATOR)

FIG.4.4. CONNECTION OF SLIDE SWITCH

When the switch is turned on to the auto side the involvement of the operator is not necessary. Keeping the switch in manual position, the forward and return carriage movements can be obtained by the different positions of the Push-Pull switch and by pressing any of the push switches provided there of. The details of the connections of the switch are shown in Fig. 4.4.

4.5 LIMIT SWITCH

Limit switch plays an important role in the execution of logic. It limits the reverse motion of the carriage to the reference end and from the change over of the contact positions a signal is derived to trigger the long duration monostable. Possible contact bounce problem is solved by providing latch for the switch contacts.

4.6 MAIN MOTOR CONTROL

The push switch on the central control panel when pressed energizes the solenoid of the contactor closing the normally open contacts thereby providing 440 V power supply to the reversing switch. The positions of the reversing switch determine the direction of rotation of the motor. The emergency stop has normally closed contacts and can be utilized on the event of danger.

The automatic haulting of the main motor after the cutting operation is completed is achieved by a relay

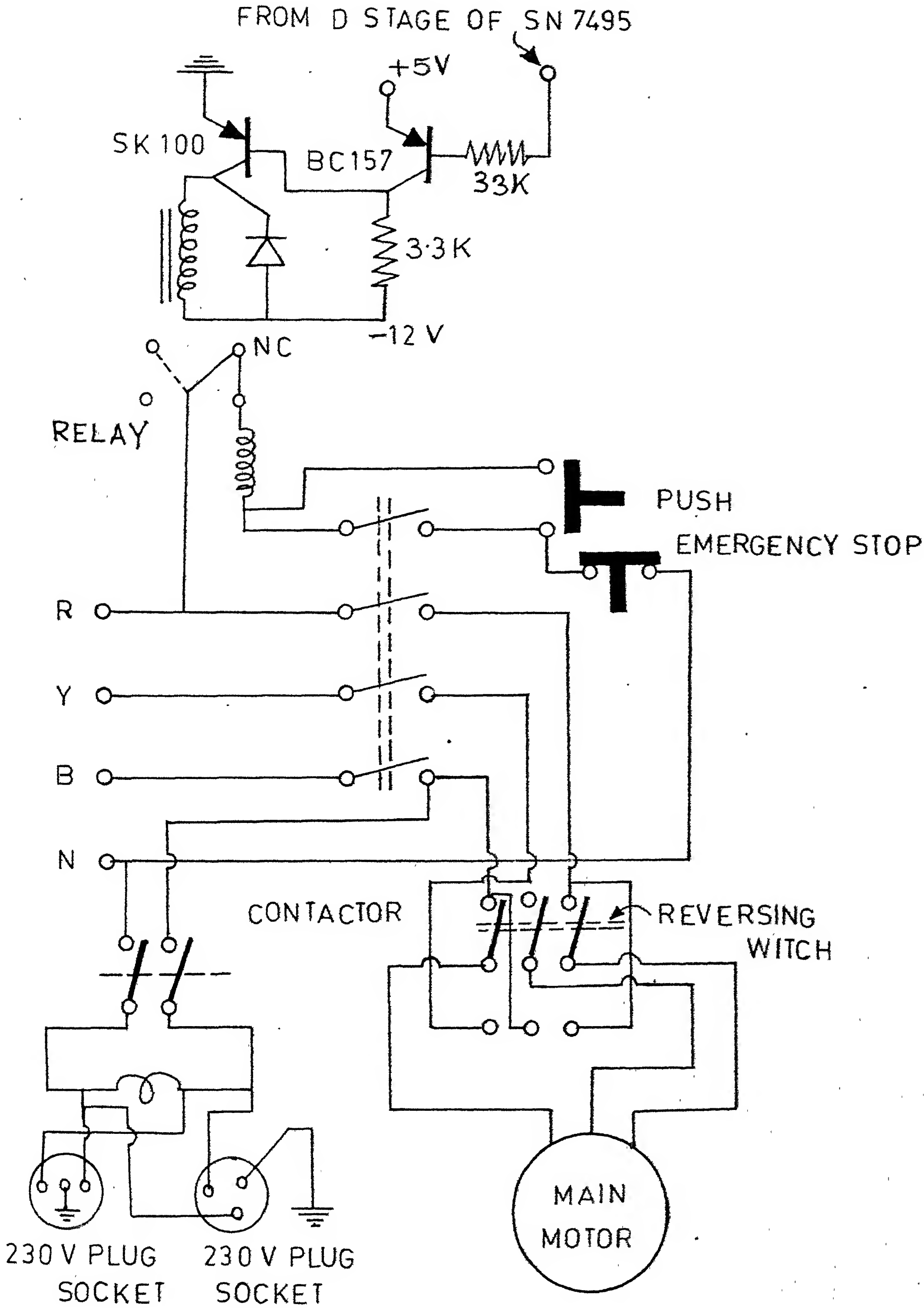


FIG.4.5. POWER CONNECTIONS

as shown in the figure. The relay driver is monitored by the 'D' stage output of the shift register. After the desired shape is obtained the 'D' stage output changes the relay contacts and hence all the power supplies will be off. The details of the connections are shown in the Fig. 4.5.

The above mentioned details are being shown in the Fig. 4.6 which includes the interconnections also.

4.7 TRANSLATOR FOR FEED STEPPER MOTOR

To suit the requirements of the feed stepper motor such as with 1.2 amperes supply to each winding at 12V, a special translator is designed and developed. It involves a two phase clock unit, the four outputs of which are amplified to obtain the required current. The amplified outputs being fed to the four motor windings. The details of the translator are shown in Fig. 4.6.

CHAPTER V

CONCLUSIONS

The present work is aimed at an unconventional way of developing a numerical control attachment for step turning on a centre lathe. Though it is developed to obtain the three steps on the workpiece, it can easily be extended for obtaining more number of steps.

It is a new approach with built-in self acting logic for controlling the motions of operative unit. It does not involve any complicated data processing in comparison to an equivalent N/C system and can easily be used on any centre lathe. It employs a hybrid circuit in controlling the cutting and auxilliary motions. One important aspect of the attachment is the resolution of the carriage and cross slide movements which are 10 microns each. The provisions such as variable feed, depth of cut and the manual adjustments are the salient features of the control system. The involvement of the operator after the finishing of cutting operations is not necessary for switching off. The machine on the event of power breakdown the system continued to be off even after the power is on. The job has to be started afresh by the operator with the switches on the control panel.

The N/C attachment is tested for the desired operations and it is found working in the manual position including switching 'on' and 'off' of the main power supply. The translator developed, in order to suit the requirements of the feed drive stepper motor, as a part of the control system is also found to be working. In the 'auto' condition, the triggering of the long duration monostable when the limit switch contacts change is observed.

The troubles faced while testing in the 'auto' mode are: the delay elements get trigger pulse from any transients in the power supply or any spurious signal in the viscinity can be avoided by incorporating a higher stabilized power supply and proper shielding. This fact is to be ascertained because the control system is found to be working well when tested on the IC board even in auto condition.

The N/C attachment can easily be extended to taper turning also with little modifications. They include the coordinated movements of operative units such as carriage and cross slide simultaneously. The slope in the taper also can be varied by feeding different clocks to the feed and cross slide drive units.

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